SEISMIC PERFORMANCE OF TRUSSES UNDER EARTHQUAKE LOADINGS

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SUPERVISOR's DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor (Hons.) of Civil Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
B. Eng (Hons.) of Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

Alhamdulillah, praise be to Allah, the most Gracious and most Merciful. With His guidance and strength, this research study has reached its end. With great pleasure, I would like to extend my sincere appreciation and thanks to my supervisor, Ir Saffuan bin Wan Ahmad for her never ending assistance and support throughout completing my research project. His comments and suggestions are very valuable for my research and without her meaningful advises it would be difficult path for me to complete this study.

I also want to express my gratitude to thank all my friends under same supervision of Ir Saffuan that gives a helpful assistance since the first day I start my research works. Their help is highly appreciated in the completion of this research.

A special thanks to my family, Yahya bin Mat Nasir and Jamilah binti Abd Hamid and my sibling who supported me in writing and motivated me to achieve my goal. Your prayers for me are greatly appreciated and encouraged me this far.

Last but not least, I would like to thank to Muhammad Aimran Amzar bin Kamaruddin, my co-supervisor for being so supportive along the way of doing my thesis. Not to forget to all who were involved directly and indirectly in helping me either through ideas, time and energy consuming, it was a great experience to work with all of you.

ABSTRACT

The study was conducted because there might be a tremors in Malaysia because we are at active tectonic plate and also there will be seismic wave generated from the earthquake that occurred in neighbouring countries. Therefore, engineers are concerned about the seismic vulnerability of trusses structures due to lack of earthquake consideration in Malaysia's building design procedure. Trusses structure is the critical structure that will damage cause by the seismic effect and also important component in building system. With this, trusses is modelled and analysed using Finite Element Modelling (FEM) by SAP2000 software under various type of analysis that cover Free Vibration Analysis (FVA), Time History Analysis (THA) and Respond Spectrum Analysis (RSA) under the different earthquake loading. The earthquake loading data is taking from Acheh and El-Centro earthquake that had been record by Malaysia Meteorological Department. Implementation between two types of different earthquake loading will represent the contrasting of dynamic characteristic of trusses structure. Furthermore, the overall seismic performance of trusses significantly enhanced in longitudinal and transverse directions. It can summarize that the design of the trusses is stable and ability to withstand under major and minor earthquake and also can yield adequate resistance against different earthquake loading.

ABSTRAK

Tujuan kajian ini dijalankan adalah Malaysia berkemungkinan besar menerima gegaran gempa bumi kerana negara kita ini berada di plat tektonik yang aktif dan juga akan menerima gelombang seismik yang dihasilkan dari gempa bumi yang berlaku di negara-negara jiran. Oleh itu, para jurutera perlu prihatin tentang kerentanan seismik bagi kekuda atap sesebuah struktur kerana kurangnya pertimbangan tentang gempa dalam prosedur reka bentuk bagi bangunan di Malaysia. Struktur kekuda atap adalah struktur kritikal yang boleh rosak sepenuhnya disebabkan beban seismik dan ianya juga komponen penting dalam system reka bentuk bangunan. Dengan ini, kekuda atap boleh dimodelkan dan dianalisis dengan menggunakan perisian SAP2000 Pemodelan Elemen Finite (FEM) dalam pelbagai jenis analisis yang merangkumi Analisis Getaran Percuma (FVA), Analisis Sejarah Masa (THA) dan Analisis Spektrum Responden (RSA) di bawah beban gempa yang berlainan. Data beban gempa yang diambil adalah dari gempa Acheh dan El-Centro yang telah diperoleh dari Jabatan Meteorologi Malaysia. Dengan mengambil kira dua jenis beban gempa yang berbeza akan menghasilkan ciri-ciri susunan dinamik yang berlainan. Tambahan pula, prestasi seismik bagi keseluruhan kekuda atap meningkat dengan ketara dalam dua arah membujur dan melintang. Ia boleh diringkaskan bahawa reka bentuk kekuda atap ini adalah stabil dan keupayaannya untuk bertahan daripada bebanan gempa yang besar mahupun kecil juga tinggi. Kekuda atap ini juga boleh menghasilkan daya tahan yang mencukupi terhadap bebanan gempa yang berbeza.

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LIST OF SYMBOLS

km	Kilometre
M_L	Local magnitude scale
Mb	Body wave magnitude
Ms	Surface wave magnitude
kgf	Kilogramforce

LIST OF ABBREVIATIONS

SAP 2000	Structural Analysis Program 2000
3D	3 Dimension
2D	2 Dimension
A.E.H.L	Augustus Edward Hough Love
OSB	Oriented Strand Board
MMD	Malaysia Meteorology Department
FVA	Free Vibration Analysis
LL	Live Load
DL	Dead Load

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earthquakes is a ground shaking caused by sudden release of energy in the earth's crust (Earthquake, 2012). An earthquake happens when two blocks of the earth suddenly slip from each other and the surface where it slip named the fault. There are two types of fault which are dip-slip fault and strike slip fault. In dip-slip fault, the blocks move from each other vertically and under this fault there being separated into two normal fault and reverse fault. Normal fault being figured as the footwall moves away from hanging wall that caused by tension and it is different with reverse fault that happen by compression that makes the footwall moves toward the hanging wall. Other than that, the strike-slip fault happens when the adjacent block moves horizontally past one another. Figure 1.1 show both types of faults.

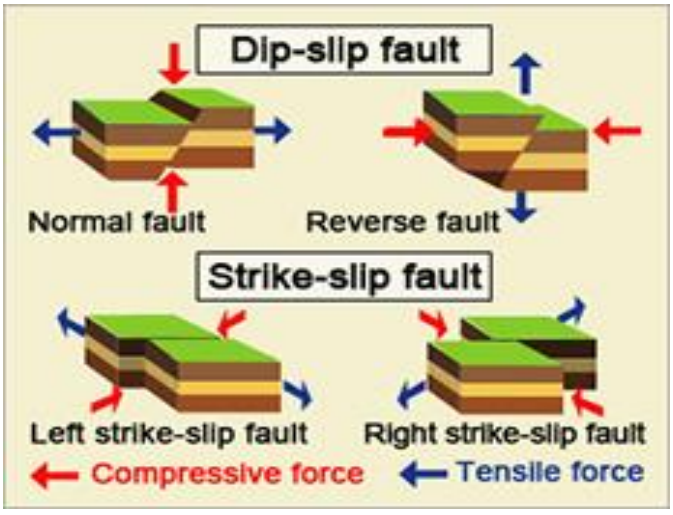

Figure 1.1 Dip-slip fault and strike-slip fault.

Sources: ("Keywords SEO Tool and Images Suggestion | SEO News | SEO Blog," n.d.)

Earthquake recently happen by smaller earthquakes first then larger earthquake follows. Earthquake being detected as foreshock until the larger earthquake happens. When the larger earthquake occurs, it being called as the mainshock and it is always have aftershocks that follow. Then the aftershock being categorized as smaller earthquakes that occur afterwards in the same place as the mainshock. Aftershocks can continue for weeks, months, and even years after the mainshock and it is depend with the size of mainshock. The most important facts is earthquakes strike entirely without warning not like hurricanes, tornados, monsoons and blizzards where can be tracked in advanced (Al-Taie & Albusoda, 2019).

All around the world, steel has become very important construction material by the end of the 19^{th}. There are many buildings used steel as truss structure and even historic monuments used iron and steel as trusses (Luong, Zabel, Lorenz, & Rohrmann, 2017). It is not just the structure was a steel but the connection between structures also used steel like pins, rivets, bolts, and welds. Structural steel very low self-weight that can give minimum load to the beam and column if the steel being use for trusses construction steel structure also high in quality and dimension precision, it is because the structure being made at factory that can protected the steel from the weather before haul to the site also the section was precise because being made using machine in the factory. Moreover, it is the most economical construction material and easy to handle and alter.

However, steel was susceptible to buckling if there any high load being applied because steel was a thin element that will lead to failure. Other than that, fire resistance are very important in steel structure it is because the strength will decreased according to heat that being applied. It also susceptible to corrosion if exposed to water and air and also can reduced the strength. In addition, fatigue also can happen especially at welded connection due to the high tensile residual stress. Figure 1.2 give a clear vision about steel trusses.

Figure 1.2 Steel structures

Sources: (“SteelConstruction.info,” n.d.)

1.2 Problem Statement

As everyone know, earthquake rarely happen in Malaysia. Even when it happened in Malaysia, it just hit in Sabah and Sarawak areas where there is many earthquake centre that have focus under it. However, it doesn’t means that peninsular Malaysia areas can’t have the earthquake. Actually the areas in Peninsular Malaysia also have the centre of earthquake but hasn’t considered as seismically active country (Shuib et al., 2017). As example of place that have the fault zone and might be reactivate fault line in peninsular Malaysia are Bukit Tinggi, Kuala Lumpur, Seremban and others.

At the same time, Malaysia is surrounded by so many active tectonic plate boundaries and also the Sunda Shelf make the country like Malaysia is being compressed. Sundaland is another name for Peninsular Malaysia because of our country are at the centre of the Sunda Shelf and our country absorbing all the stress from Sunda Shelf. There is also others country that being marked as Sundaland, as example Sumatra, Madura, Bali, Borneo, Java and smaller islands around them. So, as there is too many stress that need to be release from earth the old fault line systems might be activate as the medium to release energy from earth. Active tectonic plate around Malaysia can be seen in Figure 1.3.

REFERENCES

2D Frame Analysis software | Engissol Ltd.- Structural Engineering Software. (n.d.). Retrieved May 23, 2019, from https://www.engissol.com/2d-frame-analysis-software.html

36. The Quadrangular Truss. (n.d.). Retrieved May 24, 2019, from https://chestofbooks.com/architecture/Construction-Superintendence/36-The-Quadrangular-Truss.html

Adriaenssens, S., Liu, H., Wahed, M., & Zhao, Q. (2013). Evaluation and optimization of a traditional north-light roof on industrial plant energy consumption. *Energies*, *6*(4), 1944–1960. https://doi.org/10.3390/en6041944

AKIMA, T. (2017). Seismic Surface Waves. *Zisin (Journal of the Seismological Society of Japan. 2nd Ser.)*, *6*(1), 36–60. https://doi.org/10.4294/zisin1948.6.1_36

Aksel, H., & Eren, Ö. (2015). *A Discussion on the Advantages of Steel Structures in the Context of Sustainable Construction*. *2*(3), 46–53. https://doi.org/10.14621/tna.20150405

Al-Taie, A. J., & Albusoda, B. S. (2019). Earthquake hazard on Iraqi soil: Halabjah earthquake as a case study. *Geodesy and Geodynamics*, (April), 1–9. https://doi.org/10.1016/j.geog.2019.03.004

Binder, R., Binder, R., & Kwong, N.-H. (2016). Introductory Tutorial. *Optical Properties of Graphene*, 3–40. https://doi.org/10.1142/9789813148758_0001

Brown, J. L. (2016). The Howe Truss: From Timber to Iron. *Civil Engineering Magazine Archive*, *82*(6), 40–43. https://doi.org/10.1061/ciegag.0000563

Chapter 6 : Analysis of Structures. (2009). 1–16.

Concept, L. (2010). Richter scale. *Glossary*, 1–8. Retrieved from http://earthquake.usgs.gov/hazards/qfaults/glossary.php

Difference between Shallow Focus and Deep Focus Earthquakes | Actforlibraries.org. (n.d.). Retrieved May 23, 2019, from http://www.actforlibraries.org/difference-between-shallow-focus-and-deep-focus-earthquakes/

Earthquake, D. A. N. (2012). *Defining an earthquake*. (August).

Felipe, T. R. C., Leonel, E. D., Haach, V. G., & Beck, A. T. (2019). A comprehensive ductile damage model for 3D truss structures. *International Journal of Non-Linear Mechanics*, *112*(March), 13–24. https://doi.org/10.1016/j.ijnonlinmec.2019.02.010

Harris, C. M. (2006). *Dictionary of architecture & construction* (4th ed.). Retrieved from https://en.wikipedia.org/wiki/Scissors_truss

Havskov, J. (2011). *Earthquake location*. 1–36. https://doi.org/10.2312/GFZ.

Howe Truss. (n.d.). Retrieved May 24, 2019, from http://www.past-inc.org/historic-bridges/image-howetruss.html

Innovatieblog: Alles kan anders...en beter: Wat de schaal van Mercalli me leert over innovatie... (n.d.). Retrieved May 23, 2019, from http://kurtpeys.blogspot.com/2015/02/wat-de-schaal-van-mercalli-me-leert.html

Keywords SEO Tool and Images Suggestion | SEO News | SEO Blog. (n.d.). Retrieved May 25, 2019, from http://keywordsuggest.org/gallery/266887.htm

King Post Truss: All You Need to Know. (n.d.). Retrieved May 23, 2019, from https://gharpedia.com/king-post-truss/

Luong, H. T. M., Zabel, V., Lorenz, W., & Rohrmann, R. G. (2017). Non-destructive Assessment of the Axial Stress State in Iron and Steel Truss Structures by Dynamic Measurements. *Procedia Engineering*, *199*, 3380–3385. https://doi.org/10.1016/j.proeng.2017.09.447

Mele, T. Van, Temmerman, N. De, Laet, L. De, & Mollaert, M. (2010). Scissor-hinged retractable membrane structures. *International Journal of Structural Engineering*, *1*(3/4), 374. https://doi.org/10.1504/ijstructe.2010.033489

Method of Joints of construction | Civil Engineering. (n.d.). Retrieved May 23, 2019, from http://www.civilengineeringx.com/construction/method-of-joints/

Mohammad Rasoul Abazari | Developing of a program to analyze the general 2D trusses. (n.d.). Retrieved May 23, 2019, from https://mrabazari.mech.iut.ac.ir/content/developing-program-analyze-general-2d-trusses

Murty, C. V. R. (2008). Learning earthquake design and construction. *Resonance*, *10*(3), 88–91. https://doi.org/10.1007/bf02835843

Musson, R. (2012). Intensity and Intensity Scales. *New Manual of Seismological Observatory Practice 2*, 1–41. https://doi.org/10.2312/GFZ.NMSOP-2

No, S. R. R. (2016). *Truss Heel Heights and the Energy Requirements Structural Building Components Association (SBCA)*. (1605).

Parallel Chord Pallet Trusses. (n.d.). Retrieved May 24, 2019, from https://www.motherearthnews.com/green-homes/parallel-chord-pallet-trusses

Patil, A. S., & Kumbhar, P. D. (2013). Time History Analysis of Multistoried Rcc Buildings for Different Seismic Intensities. *International Journal of Structural and Civil Engineering Research*, *2*(3), 195–201.

Quantum Na. (n.d.). Retrieved May 25, 2019, from http://quantumna.blogspot.com/

Queen Post Truss: All You Need to Know. (n.d.). Retrieved May 23, 2019, from https://gharpedia.com/queen-post-truss/

R021b North Light Engine Shed - Scalescenes. (n.d.). Retrieved May 24, 2019, from https://scalescenes.com/product/r021b-north-light-engine-shed/

RAISED-HEEL TRUSS : Also called an energy truss, is a roof truss that is designed to reduce energy losses. A vertical extension at th… | ARE : SS terms in 2019…. (n.d.). Retrieved May 24, 2019, from https://www.pinterest.com/pin/524247212846529172/

Richter Scale & Magnitude. (n.d.). Retrieved May 23, 2019, from https://www.sms-tsunami-warning.com/pages/richter-scale#.XOa8Q4gzbIV

SAP2000 v14 Structural Analysis Software | KulasCivilWorks. (n.d.). Retrieved May 24, 2019, from https://kulascivilworks.wordpress.com/2010/07/13/sap2000-v14-structural-analysis-software/

Shuib, M. K., Manap, M. A., Tongkul, F., Bin, I., Rahim, A., Jamaludin, T. A., … Ahmad, Z. (2017). *Active Faults In Peninsular Malaysia With Emphasis On Active Geomorphic Features Of Bukit Tinggi Region*. *1*(1), 13–26.

SteelConstruction.info. (n.d.). Retrieved May 23, 2019, from https://www.steelconstruction.info/The_Steel_Construction_Information_System

Structural analysis - Wikipedia. (n.d.). Retrieved May 23, 2019, from https://en.wikipedia.org/wiki/Structural_analysis

UpSeis. (2007). What are seismic waves? *2007*. Retrieved from http://www.geo.mtu.edu/UPSeis/waves.html

USGS.gov | Science for a changing world. (n.d.). Retrieved May 25, 2019, from https://www.usgs.gov/

Utah Building Lumber | Sunroc Building Materials. (n.d.). Retrieved May 24, 2019, from https://sunrocbuildingmaterials.com/products/lumber/

Weblet Importer. (n.d.). Retrieved May 23, 2019, from https://www.cs.princeton.edu/courses/archive/fall09/cos323/assign/truss/truss

Yashavantha Kumar, G. A., & Sathish Kumar, K. M. (2017). Free vibration analysis of smart composite beam. *Materials Today: Proceedings*, *4*(2), 2487–2491. https://doi.org/10.1016/j.matpr.2017.02.101